

# *Status of ADS Development in Japan*

*Hiroyuki Oigawa*

*Japan Atomic Energy Research Institute*

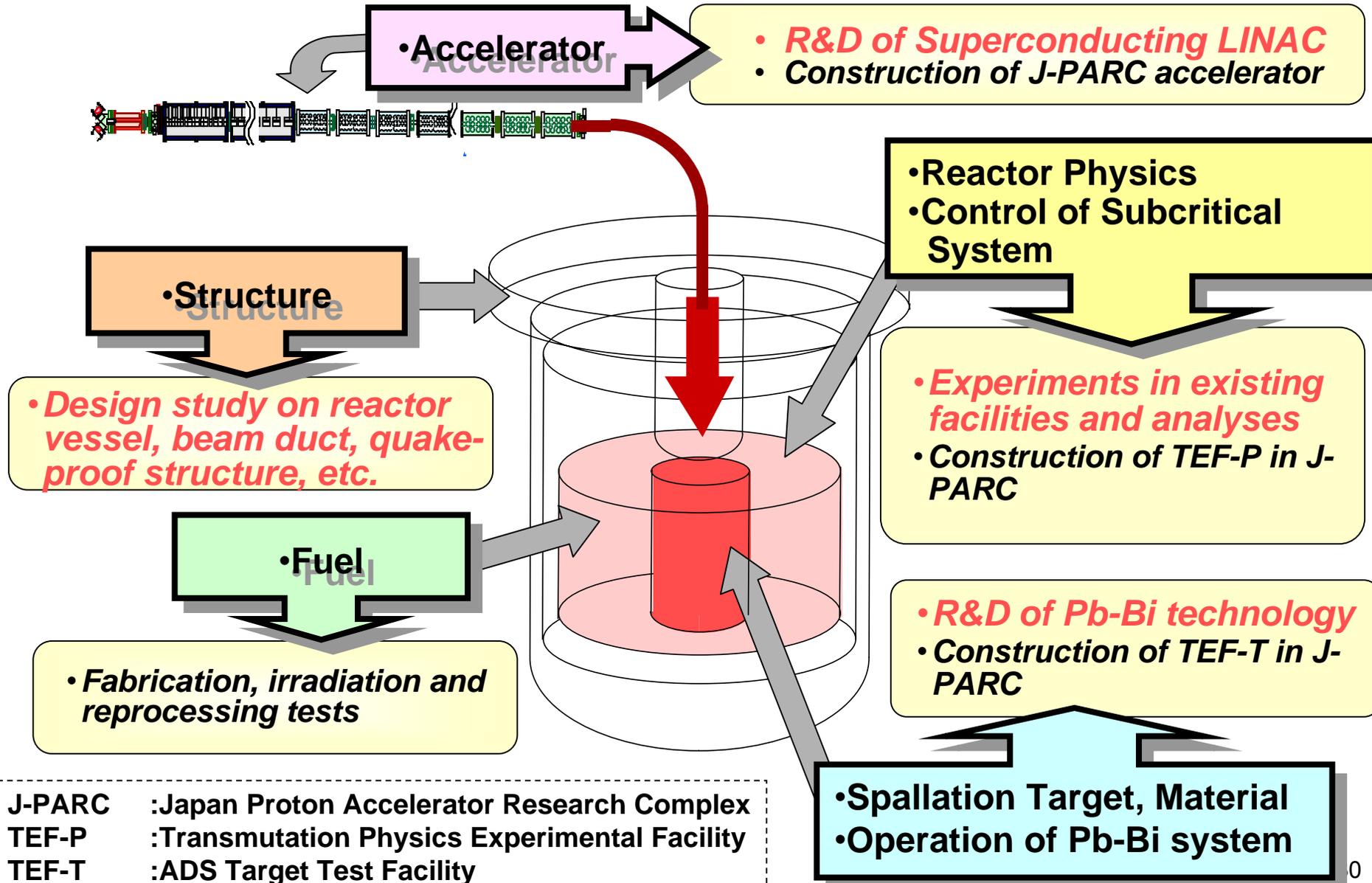


- R&D in the framework of “Development Program of Innovative Nuclear System Technology” supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in Japan.
- Status of the High Energy Proton Accelerator Project: J-PARC and the Transmutation Experimental Facility

# Overview of MEXT Program

- Since 2002, the MEXT started a new scheme that calls for research and development activities on **innovative nuclear technologies under competitive conditions** brought forth by public invitation of relevant projects
- In 2002, 9 projects were selected out of 42 proposals.
- **“3-year R&D on ADS by JAERI”** and **“KUCA-FFAG Coupling by Kyoto Univ.”** were two of selected proposals.
- **“Development of MA Cross Section Data”** was also selected.
- The Program by Kyoto University is explained by Prof. Mishima.
- The Program by JAERI is explained hereafter.

# Fields of R&D for ADS



# Outline of the Program

The 3-year R&D program on **Accelerator-Driven Transmutation System (ADS)** has started since 2002, conducted by JAERI together with 12 institutes, universities and private companies.

- R&D on **Superconducting Linear Accelerator (SC-LINAC)**
- R&D on **Lead-bismuth Technology** for Spallation Target and Core Coolant (**Dr. Kurata's presentation**)
- R&D on **Subcritical Core Design and Physics**

# Framework of the R&D Program

KEK :High Energy Accelerator Research Organization  
JNC :Japan Nuclear Cycle Development Institute  
TIT :Tokyo Institute of Technology  
MHI :Mitsubishi Heavy Industries, LTD.  
MES :Mitsui Engineering & Shipbuilding Co., Ltd.  
MELCO :Mitsubishi Electric Corp.  
NFD :Nippon Nuclear Fuel Development Co., Ltd.  
Kaken :Kaken Co. Ltd.

**Organizer  
JAERI**

## (1) R&D on Superconducting LINAC (SC-LINAC)

a. Manufacturing of a  
Prototype Cryomodule  
(JAERI, KEK, MHI)

b. System Design of SC-  
LINAC  
(JAERI, MELCO)

## (2) R&D on Pb-Bi Spallation Target and Coolant

a. Corrosion of Structural  
Material  
(MES, JAERI, Tohoku-U)

b. Thermal-hydraulics at  
Beam Window  
(JAERI, MES, Hokkaido-U)

c. Behavior of  
Radioactive Impurity  
(JNC, JAERI, TIT, NFD,  
Kaken)

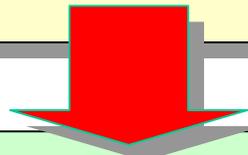
## (3) R&D on Subcritical Core Design and Physics

a. Design of Subcritical Core  
and its Engineering Feasibility  
(JAERI, MHI)

b. Reactor Physics of  
Subcritical Core  
(JAERI, Kyoto-U, Nagoya-U)

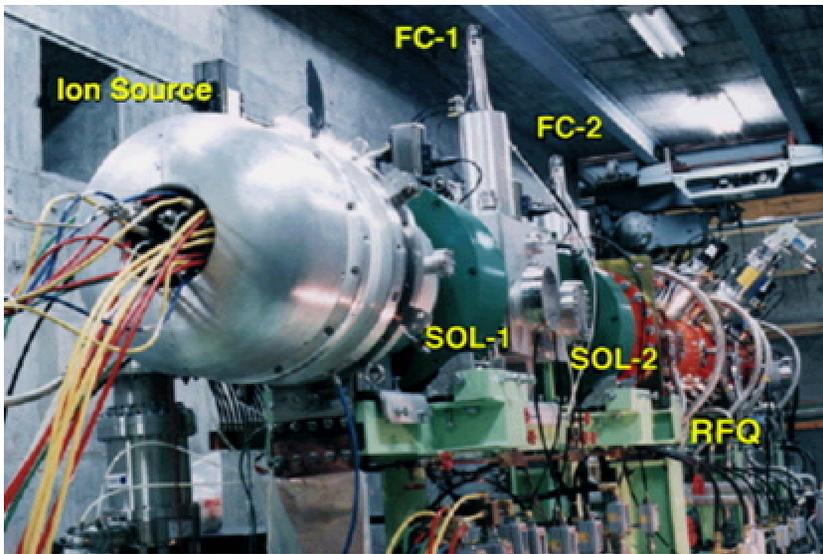
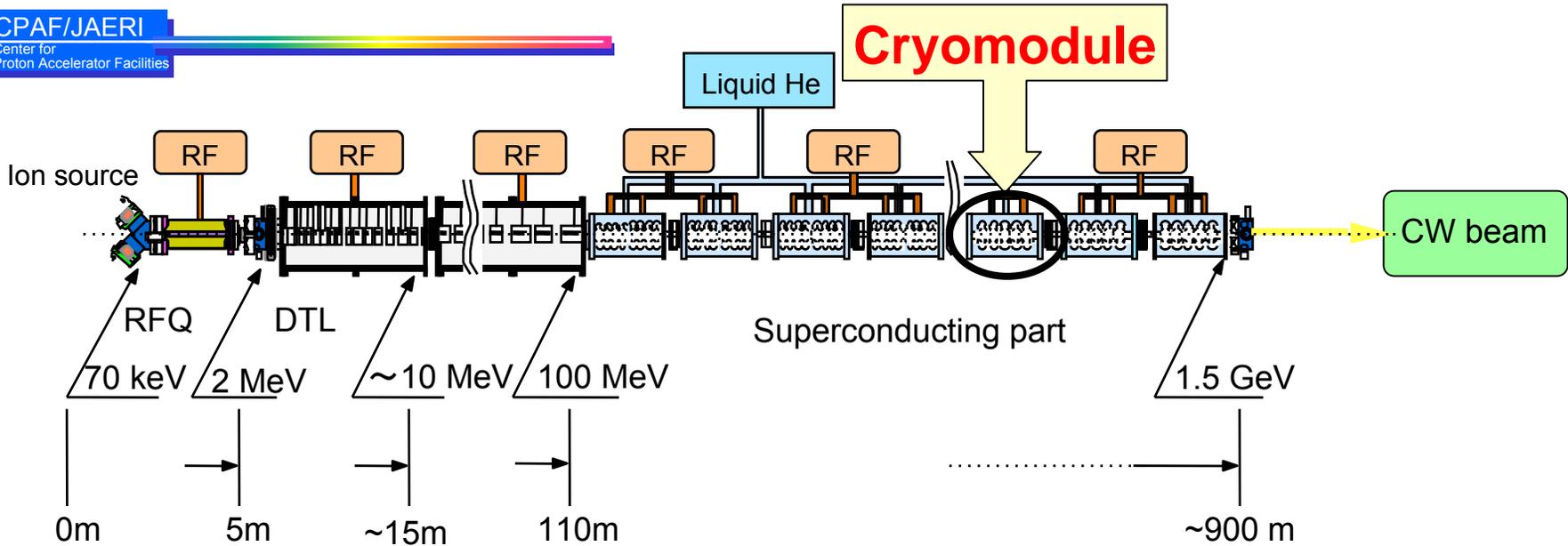
# *(1) R&D on Superconducting LINAC (SC-LINAC)*

- a. **Manufacturing and test of cryomodule**  
(JAERI, KEK, MHI)
  - Demonstration of high performance for acceleration electric field and cooling
- b. **System design of SC-LINAC (JAERI, KEK, MELCO)**
  - Optimization of whole accelerator system



**To demonstrate feasibility of accelerator system which is applicable to ADS , where high acceleration performance, high efficiency and low cost are required.**

# SC-LINAC

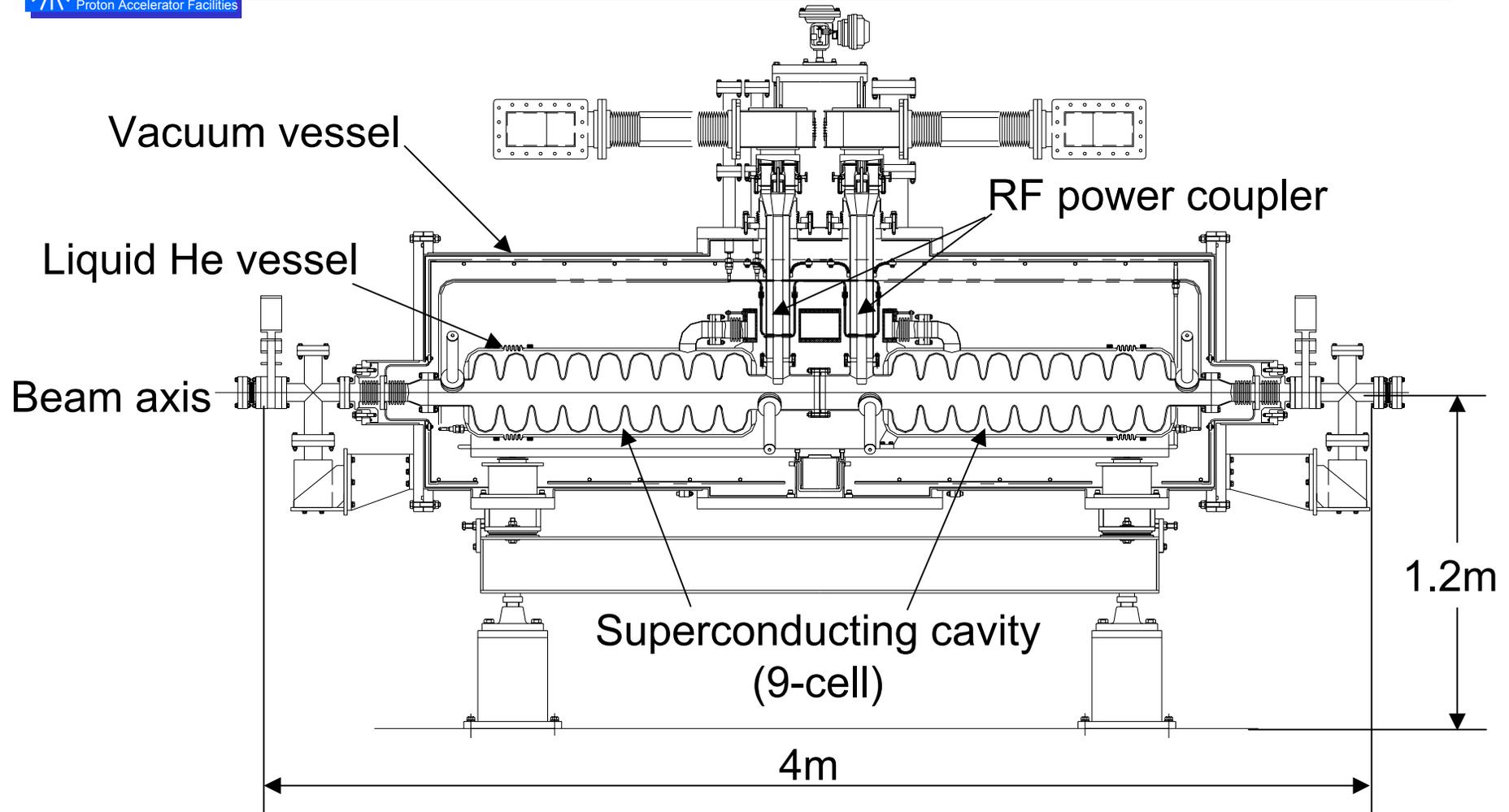


RFQ high current test :  
70 mA



SC-cavity single cell test :  
44 MV/m (2.1 K)

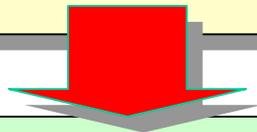
# Manufacturing of a Prototype Cryomodule



- 972MHz,  $\beta=0.725$  ( $E_p=424\text{MeV}$ ).
- Targeted maximum surface electric field is 30 MV/m
- Assembling : FY2003. Measurement : FY2004.

## *(2) R&D on Pb-Bi Spallation Target and Coolant*

- a. **Material corrosion and purity control (JAERI, MES, Tohoku-U)**
  - Establishment of corrosion database by changing oxygen concentration, flow velocity, etc.
  - Development of purity control system and oxygen sensor
- b. **Thermal hydraulics (JAERI, MES, Hokkaido-U)**
  - Loop test of beam window cooled by Pb-Bi
  - Development of ultrasonic velocity probe
- c. **Behavior of radioactive material (JAERI, JNC, TIT,...)**
  - Evaporation test for irradiated Pb-Bi (especially for Po)
  - Improvement of analytical prediction for SP amount



**To accumulate database and experience for Pb-Bi as spallation target and coolant**

# Thermal-hydraulic Loop



- Temperature: 330~430 °C
- Flow speed: 0.8~2 m/s
- Heater: 6 kW (max.)
- Mechanical pump: 500 Litter/min.

# *(3) R&D on Subcritical Core Design and Physics*

## **a. Feasibility study from engineering aspects**

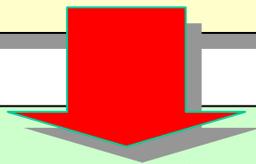
**(JAERI, MHI)**

- Proposal of technologically realistic design for core structure

## **b. Development of subcriticality monitoring method and evaluation of neutronics design accuracy**

**(JAERI, Kyoto-U, Nagoya-U)**

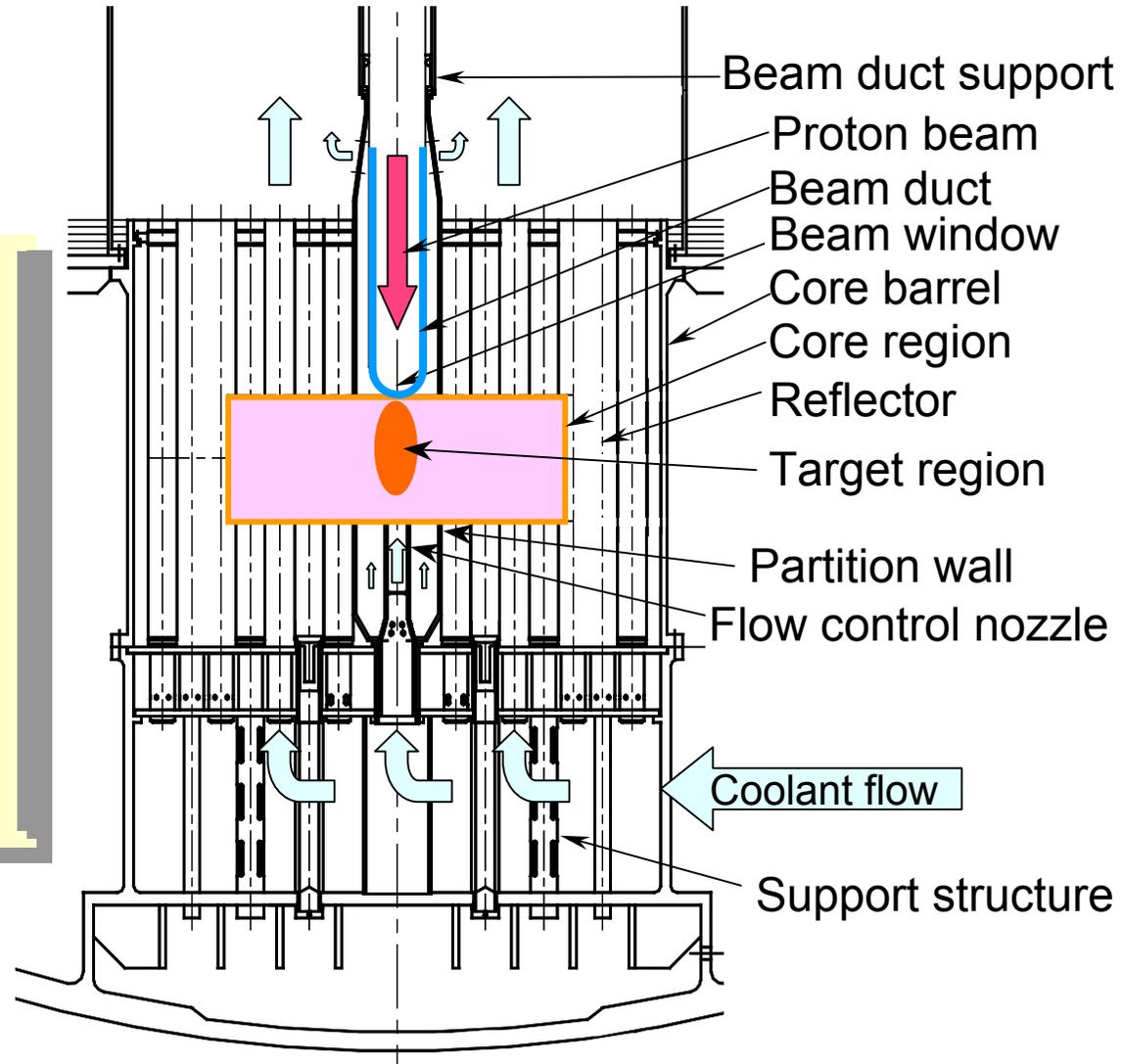
- Experimental study using KUCA and FCA
- Sensitivity analysis on reactor physics parameters



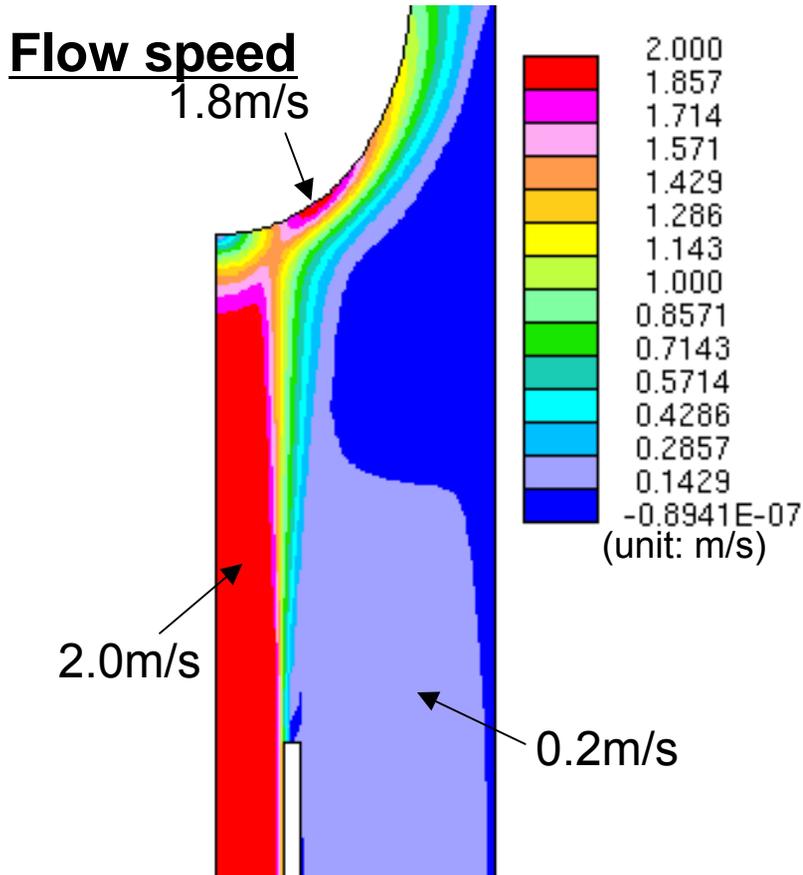
**To establish realistic concept of ADS and reliable design method**

# Design Study around Beam Window

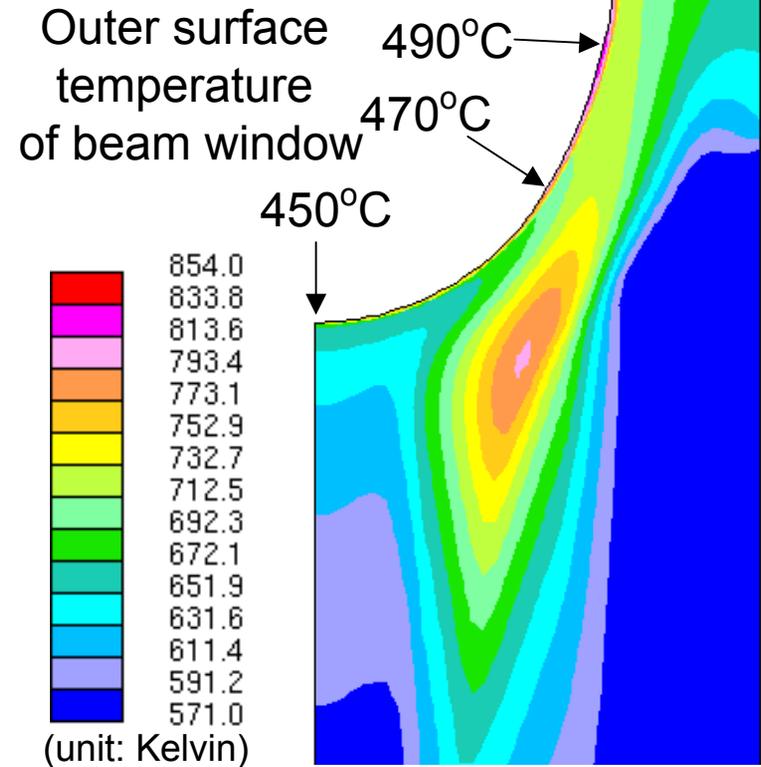
- Partition wall
- Uniform flow rate among fuel assemblies (2m/s)
- Flow control nozzle
- Optimization of design parameters:
  - Inlet temp. : 300 °C
  - Beam duct : 45cm



# Hydraulic Analysis

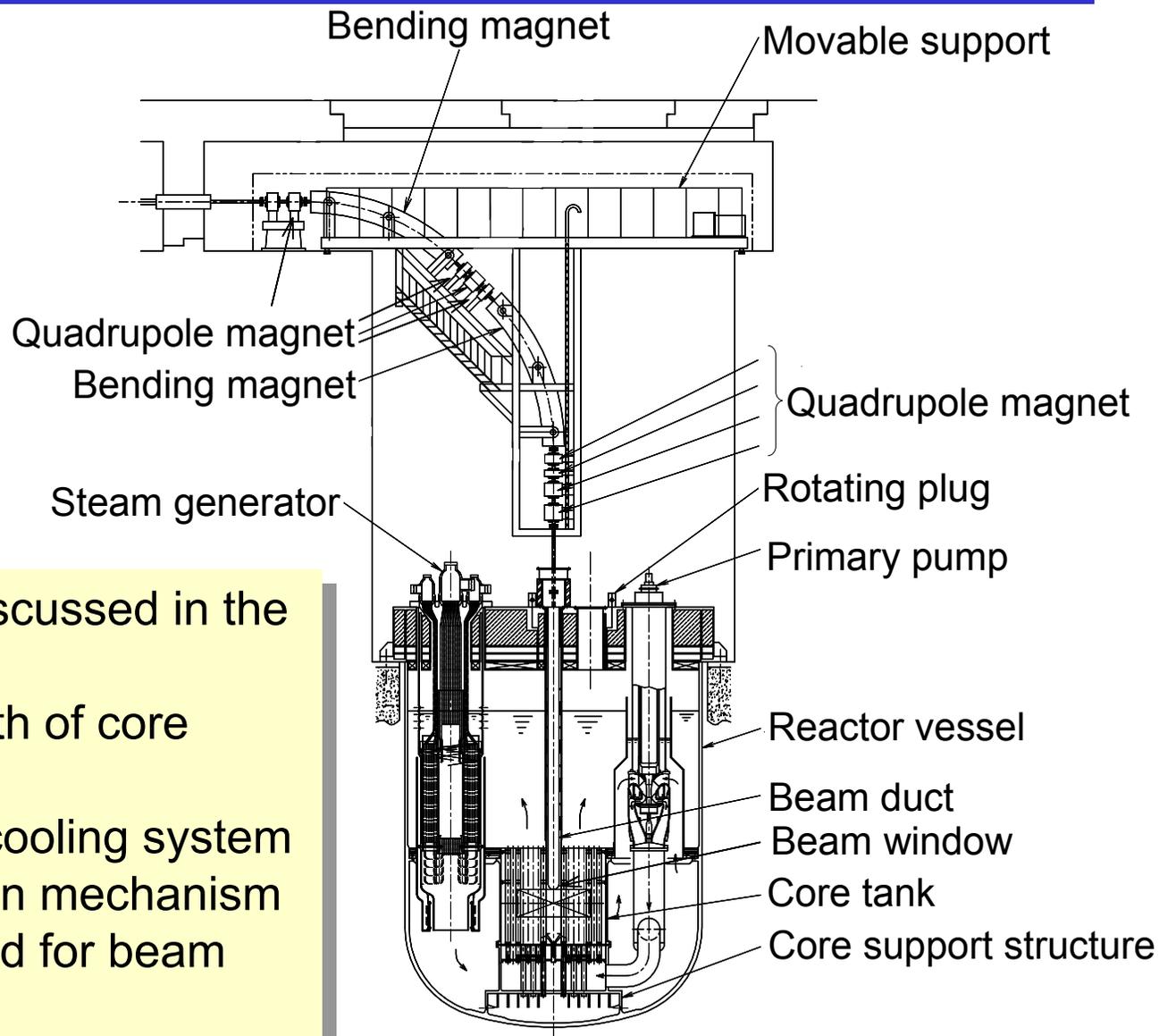


**Temperature**



- Maximum temperature of outer surface : 490 °C
- Flow control nozzle cools the bottom of the beam window effectively.

# Basic Design of ADS Structure



Other items to be discussed in the program:

- Structural strength of core
- Shielding
- Basic design of cooling system
- Beam introduction mechanism
- Exchange method for beam window and fuel
- Whole plant arrangement

# Reactor Physics of Subcritical Core Fuel Composition

## Fuel composition at initial loading

Item	Composition
Chemical Form	MA(60wt%) + Pu(40wt%) mono-nitride
Diluent	HM : Zr = 40 : 60 (wt%)
MA (wt%)	$^{237}\text{Np} / ^{241}\text{Am} / ^{243}\text{Am} / ^{244}\text{Cm} = 46.4 / 37.1 / 12.7 / 3.8$
Pu (wt%)	$^{238}\text{Pu} / ^{239}\text{Pu} / ^{240}\text{Pu} / ^{241}\text{Pu} / ^{242}\text{Pu} = 2.7 / 55.3 / 23.9 / 11.0 / 7.1$

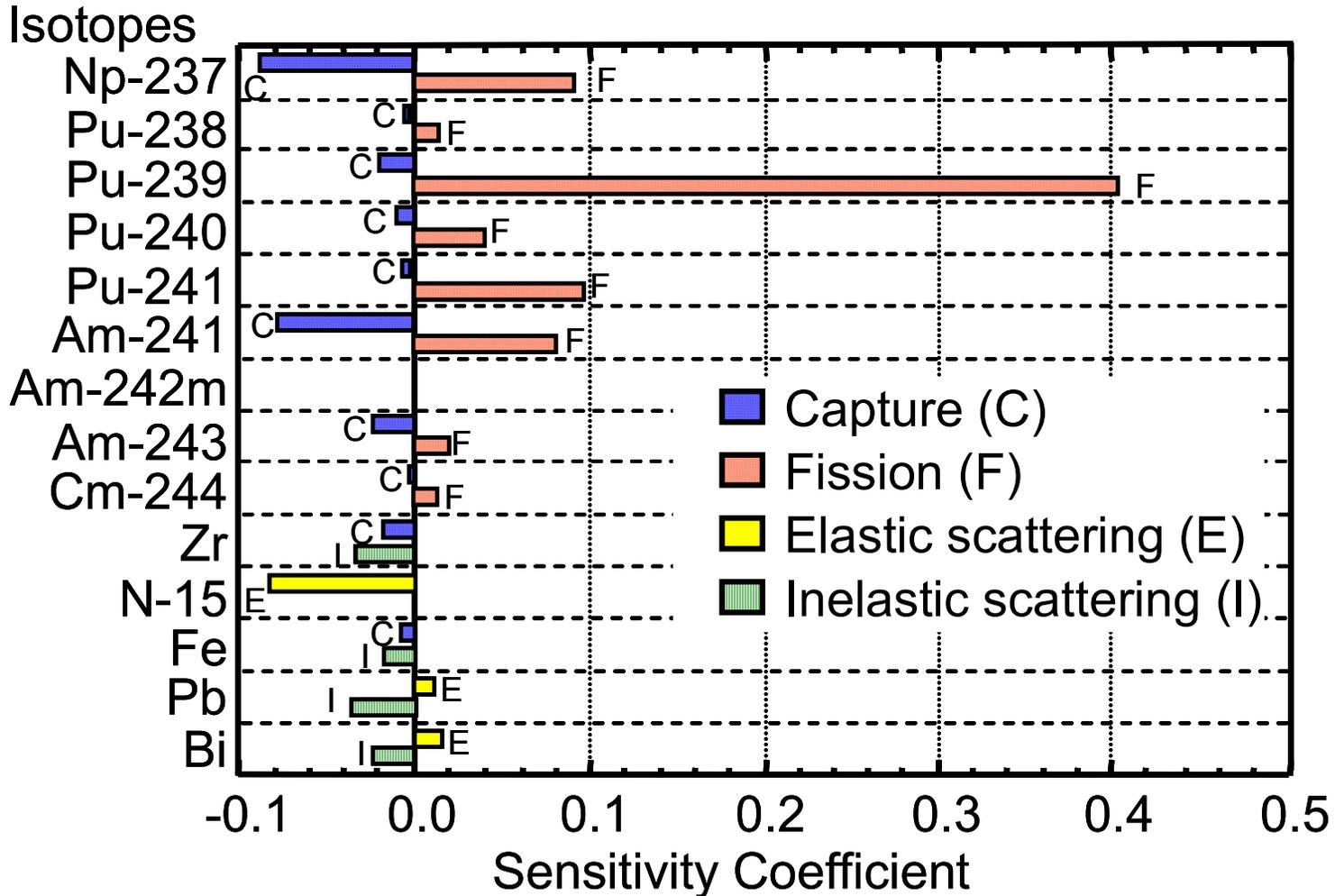
### ● Characteristics of the fuel:

- U-238 is not contained and large amount of MA is loaded.
- Pu is added at initial loading to minimize burn-up reactivity swing.
- Nitrogen-15 is used to avoid C-14 production.
- ZrN is added as the inert diluents.

- To evaluate prediction accuracy of reactor physics parameters of such “strange” fuel composition, sensitivity analysis was performed by SAGEP code.

# Reactor Physics of Subcritical Core

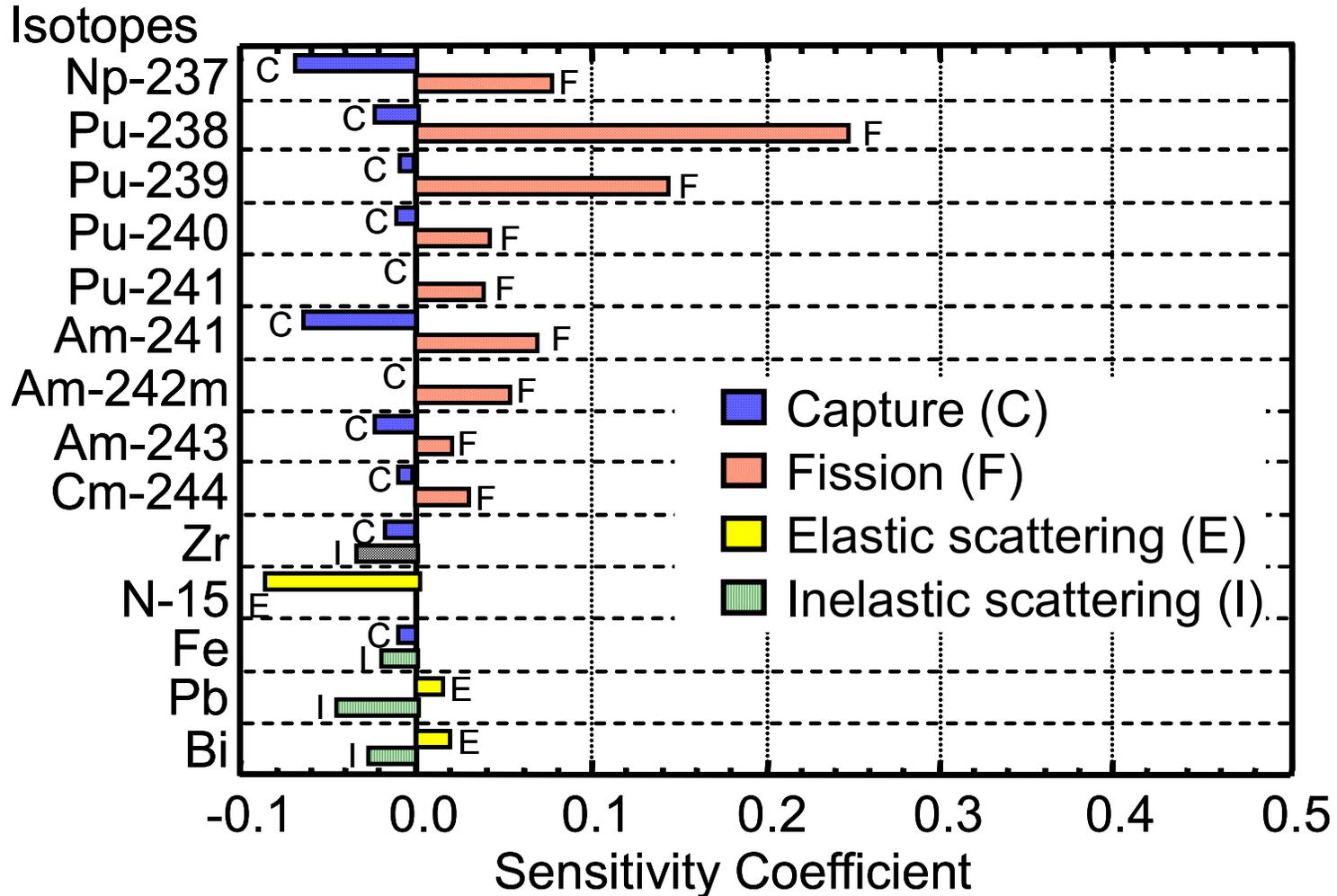
## Sensitivity of Nuclear Data to $k_{eff}$ (1)



(a) Beginning of 1st. cycle

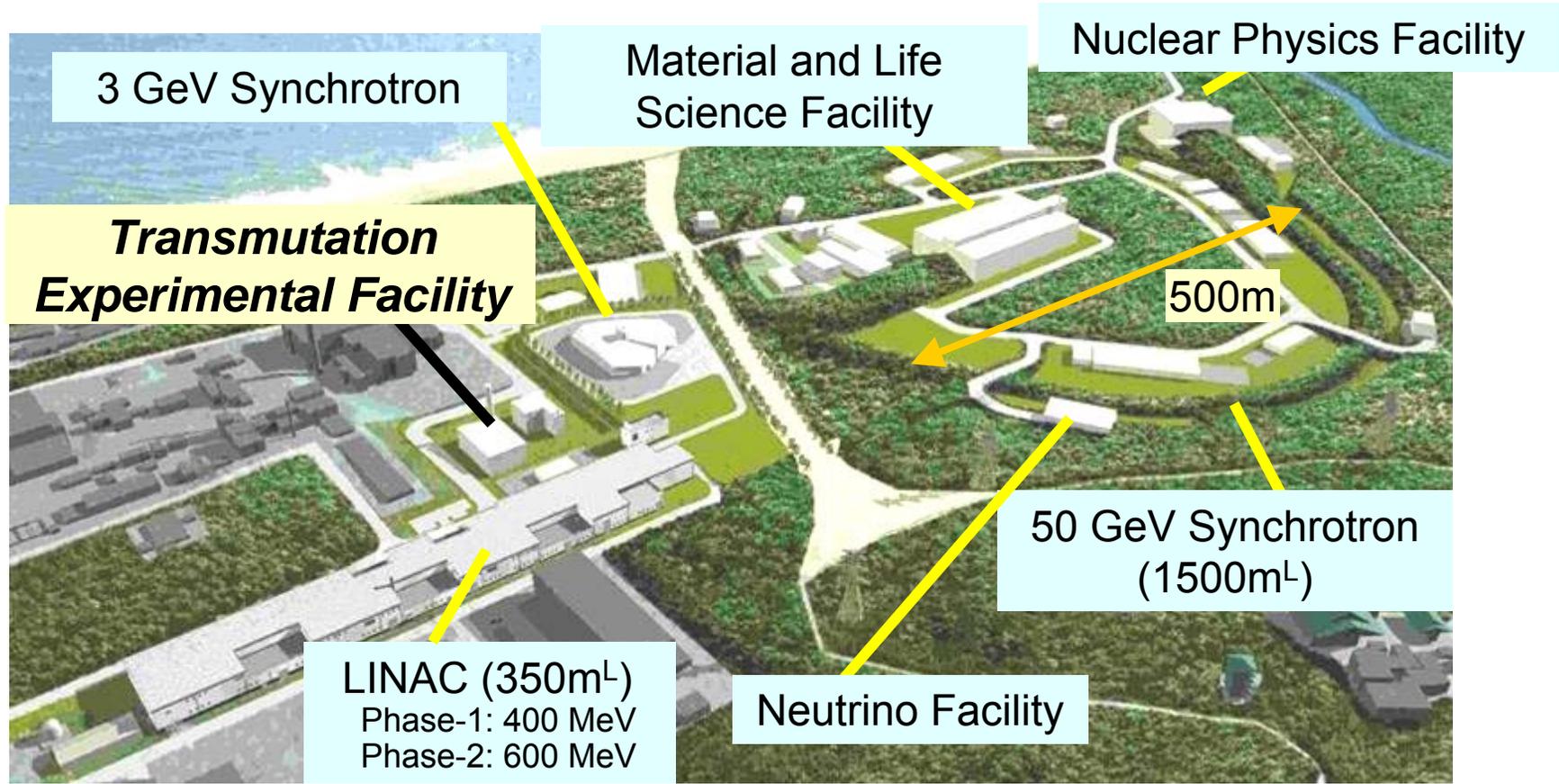
# Reactor Physics of Subcritical Core

## Sensitivity of Nuclear Data to $k_{eff}$ (2)



(b) Beginning of 5th. cycle

# J-PARC : Japan Proton Accelerator Complex



# Present Status of J-PARC (1)



LINAC

# Present Status of J-PARC (2)



LINAC and site for TEF

# Present Status of J-PARC (3)



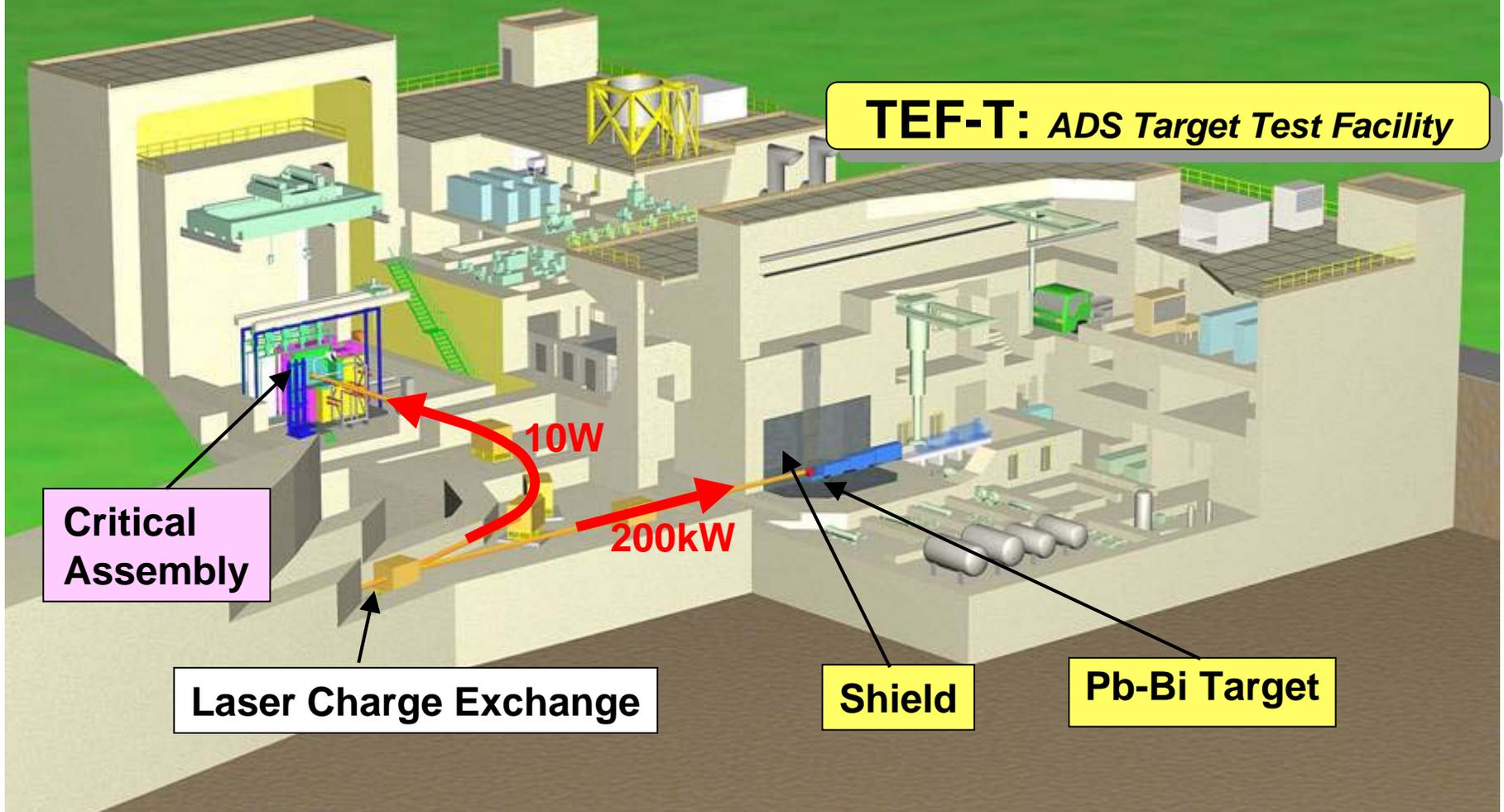
May 2004

LINAC to 3GeV-PS

# Transmutation Experimental Facilities

**TEF-P:** *Transmutation Physics Experimental Facility*

**TEF-T:** *ADS Target Test Facility*



**Critical  
Assembly**

**Laser Charge Exchange**

**10W**

**200kW**

**Shield**

**Pb-Bi Target**

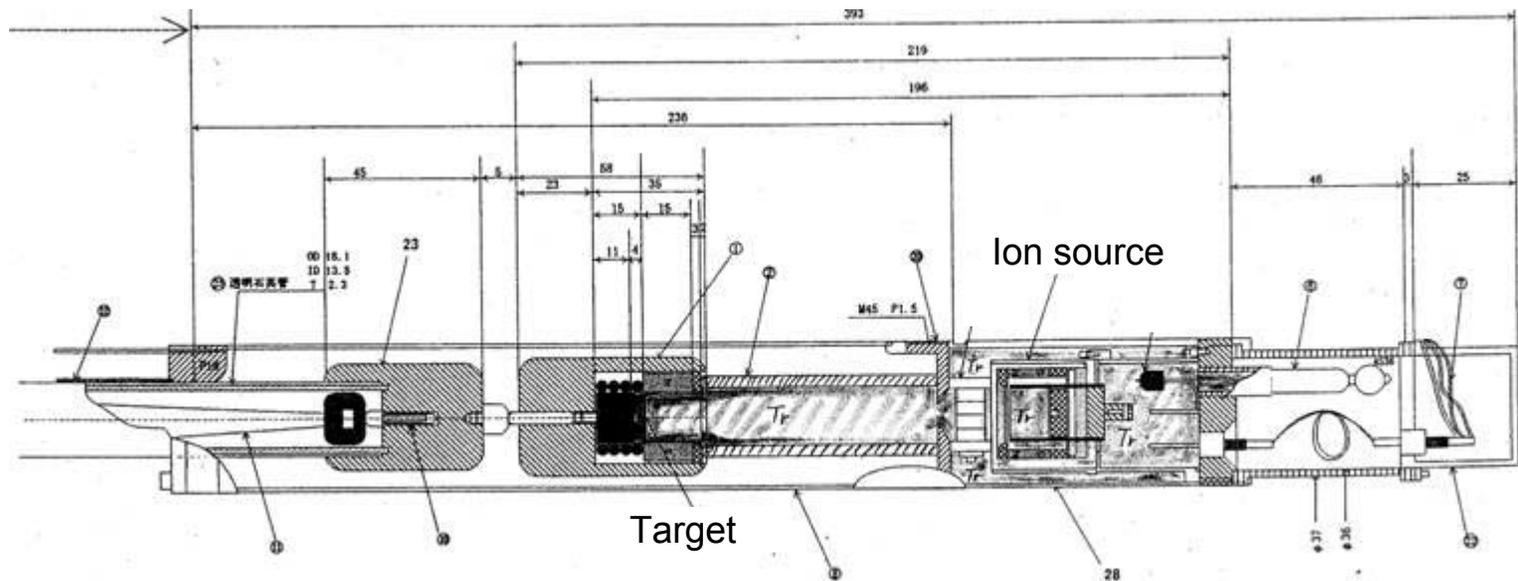
# Program Plan (Preliminary)

- Check and Review (C&R) by Atomic Energy Commission will be necessary to start TEF.
- Safety review is necessary for TEF-P before the construction and the manufacturing because it is a nuclear reactor facility.
- R&Ds for TEF:
  - TEF-P: Instrumentation, Laser charge exchange
  - TEF-T: Pb-Bi technology, Material irradiation effect

Fiscal Year		2003 H15	2004 H16	2005 H17	2006 H18	2007 H19	2008 H20	2009 H21	2010 H22	2011 H23	2012 H24	
Milestone				▼ Establishment of New Organization			▼ Licensing of TEF-P					
			↔ C&R					↔ C&R				
J-PARC	LINAC	180MeV					400MeV					
		600MeV					600MeV					
	TEF	TEF-P	R&D, Design			Safety review		Construction			Commissioning	
		TEF-T	R&D, Design			Safety review		Construction			Commissioning	

# R&D Activities for TEF-P (1)

## Manufacturing Pulse Neutron Generator for FCA experiment



### ● Specification

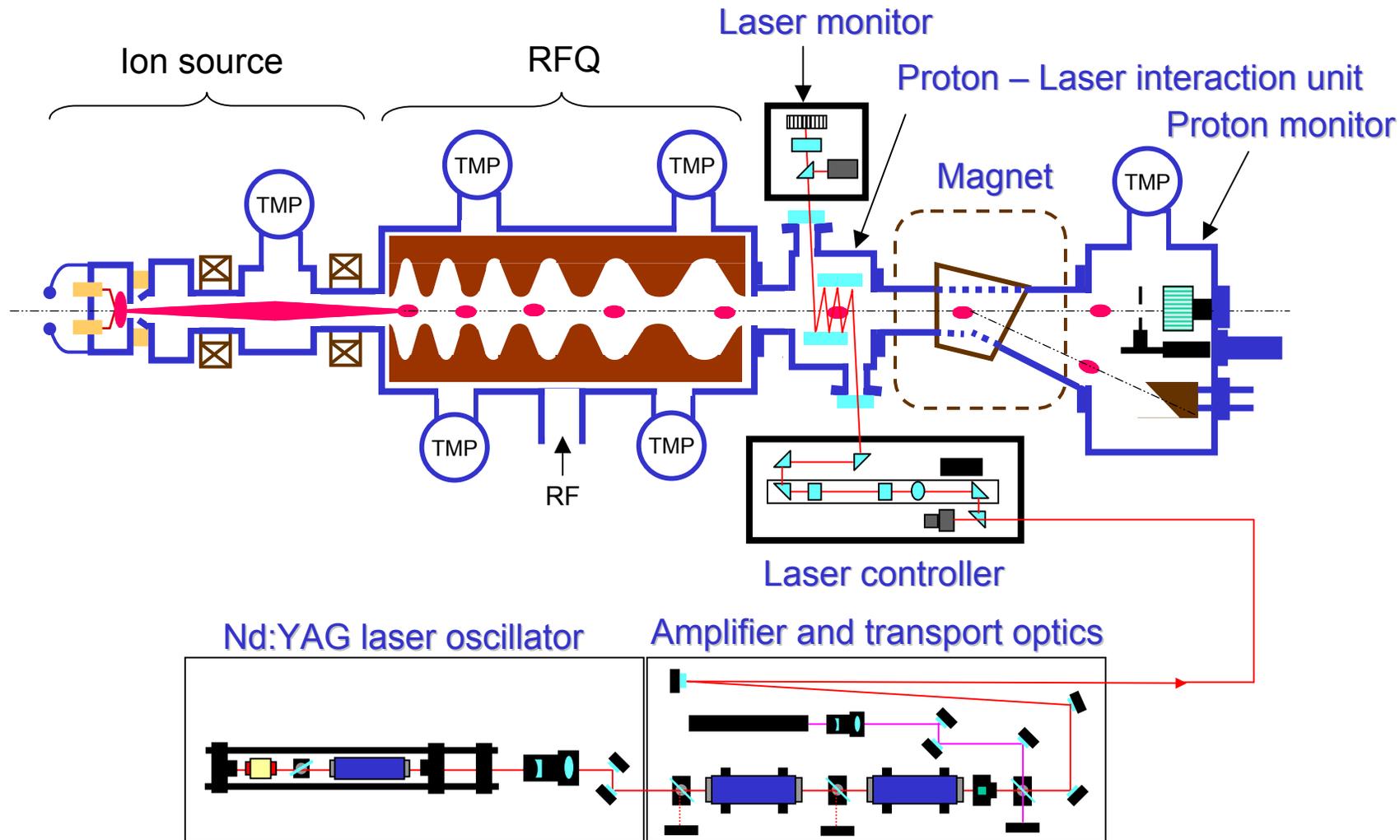
- Reaction : D-T (14MeV)
- Neutron source strength :  $1 \times 10^8 \text{n/s}$
- Pulse width :  $< 5 \mu \text{s}$
- Repetition : 10 kHz – continuous
- Diameter :  $< 5 \text{cm} \phi$  (to be inserted in FCA matrix structure)

### ● Purpose

- To verify reactor instrumentation for TEF-P
- To develop subcriticality monitoring method

# R&D Activities for TEF-P (2)

## Installation of Laser Charge Exchange Test Device



# R&D Activities for TEF-T (1)

## 3000-hour test by Pb-Bi loop

Test temperature : 450°C  
(High temperature part)  
Temperature gradient : 50 -100°C  
EMP power : 5 l/min  
Velocity at test section : 1m/sec  
Flow meter : Electromagnetic type  
Pb-Bi inventory : 0.018m<sup>3</sup>  
Material of components and  
specimen : type 316ss  
Cover gas : 99.995% Ar  
Testing time: ~3000h

- Specimen for 1<sup>st</sup> operation is under investigation.
- 2<sup>nd</sup> & 3<sup>rd</sup> operation was successfully completed.

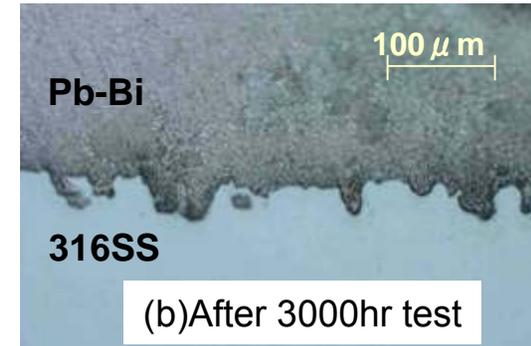
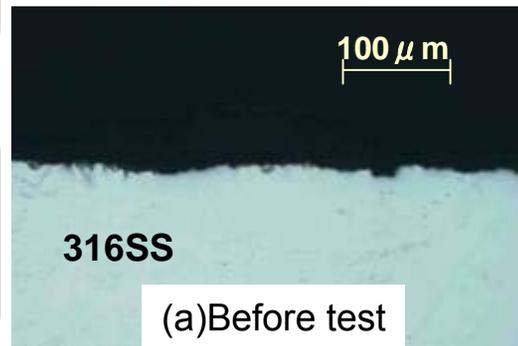
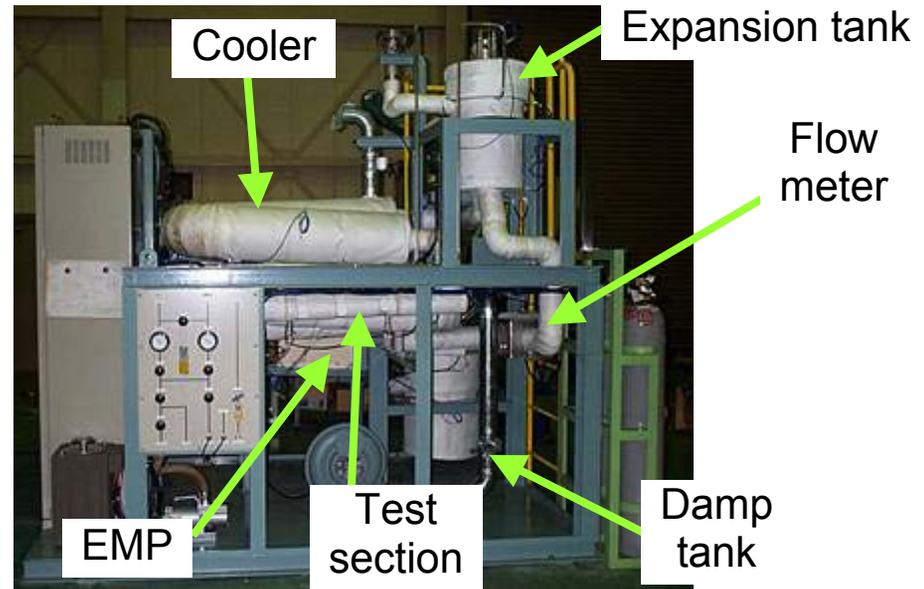


Fig. Result of Pb-Bi loop test for 316SS

# *R&D Activities for TEF-T (2)*

## *Other Activities for TEF-T Pb-Bi Target*

- **Static corrosion experiment**
  - **TIARA triple ion irradiation**
  - **PIE of samples irradiated at SINQ (590MeV proton) of PSI, Switzerland**
  - **MEGAPIE international collaboration**
  - **Polonium filtering test**
  - **Rinse of Pb-Bi stuck to materials**
- **Details are to be presented by Dr. Kurata.**

# *Other R&D Activities for ADS in Japan*

## ● **Kyoto University:**

- Experimental program for coupling of critical assembly (thermal neutron) and proton beam started in 2002.
- Accelerator-Driven Subcritical Reactor is planned not only for transmutation but also for energy production and thorium utilization.

## ● **Tohoku University:**

- Conceptual design of ADS for transmutation is studied.

## ● **Tokyo Institute of Technology (TIT):**

- Optimization of spallation target is studied.

## ● **Nagoya University:**

- Measurement method for subcriticality of ADS is studied.

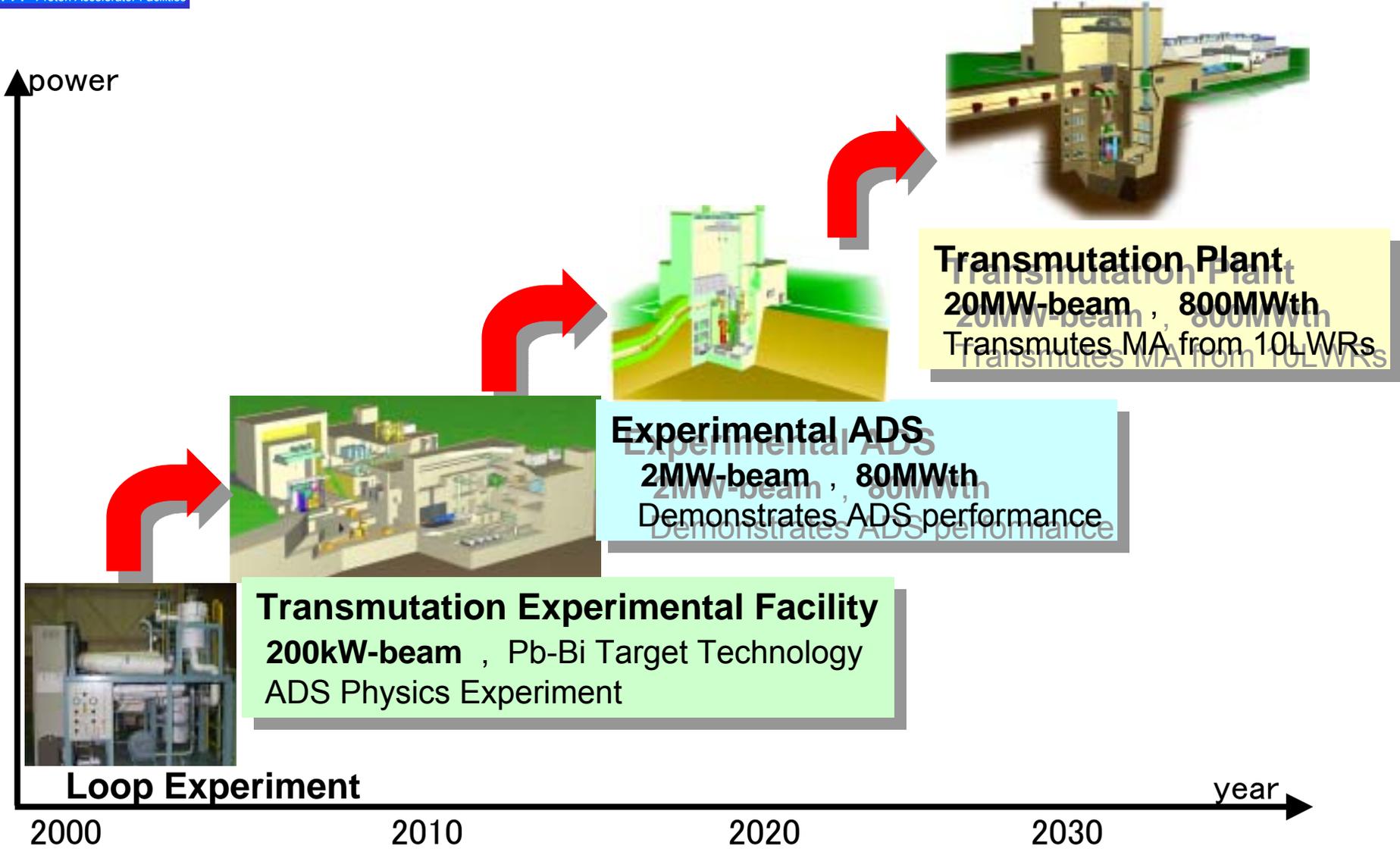
## ● **Pb-Bi** (not only for ADS but also for steam generator or coolant of FR) :

- Mitsui E&S, TIT, Osaka Univ., CRIEPI, .....

## ● **Nuclear Data :**

- Several universities and institutes measure MA data, FP data and high energy data

# R&D Scenario of ADS



# *Concluding Remarks*

- **The “MEXT Framework” encourages the international collaborations**
- **Although it may be difficult to distribute the budget under this framework, it must be possible to accept foreign researchers.**
- **“JAERI’s 3-year R&D on ADS” will finish FY2004.**
- **It should be one possibility to establish an international consortium by Asian countries to apply to the next term.**
- **We welcome the participation in TEF of J-PARC.**